Generating Trigger Primitives from an EIC Electromagnetic Calorimeter

Martin L. Purschke, John Kuczewski, Sean Stoll, Craig Woody
Brookhaven National Laboratory

Virtually every proposal for an EIC detector includes full azimuthal and pseudo-rapidity coverage with a compact electromagnetic calorimeter. The EmCal-related R&D for the EIC principally takes place within the eRD1 Collaboration (the EIC Calorimeter Consortium), but also draws on designs and measurements performed by the BNL sPHENIX collaboration.

We are proposing to develop and demonstrate the generation of trigger primitives in the front-end system of an electromagnetic calorimeter at the Electron-Ion Collider. This would allow to trigger on collisions with particular properties and signatures, such as high-p_T clusters, or signatures from mesons decaying into photons or $e^+ - e^-$, such as π^0, η, or Υ. If desired or needed, this system could run in a trigger-less mode altogether.

Trigger Strategies in Collider Experiments

Different from fixed-target experiments, the moment when collisions can occur are fixed in time – the moment when bunches cross. This also determines the times when signals from detectors arrive at the respective front-end electronics (FEE) inputs, and when the FEEs need to be instructed to preserve the digitized data to be transmitted up the DAQ chain. The depth of the buffers in the front-end, together with the sample rate, determines the maximum trigger latency, the time until a yes/no decision must have propagated back to the FEE in order to capture the data. For example, with a sample rate of 10 MHz and a buffer depth of 1000 samples, the decision has to arrive within 100 microseconds.

That trigger latency allows to refine triggers to select truly interesting events for logging. This is normally done by implementing level-2 and level-3 triggers, which perform an analysis of the data to determine whether or not interesting features are to be found in the data of a given collision.

Performing a full analysis of the full data of a given event within the time constraints of the trigger system is impossible. This is why the front end electronics units, such as a front-end card, must perform as much processing on the data in its purview as possible to characterize the data and generate a short summary report, usually few hundred bytes. These so-called *trigger primitives* are sent to the trigger system through a fast data path to give the system time to arrive at a decision. The amount and speed of available processing, in addition to the fraction of the data of the detector available for processing, determine the quality of such a determination and also the trigger efficiency. For a simple example, if the view of a FEE card is only a 8x8 sub-array of calorimeter towers, it will be very hard to derive any meaningful characteristics, to a large part due to boundary effects of the small array. If, however, a given front-end unit looks at a substantial larger sub-array of the calorimeter, quantities such as the energy contents of overlapping 2x2 or 3x3 arrays can be computed, and the highest value (or, for example, the 10 highest such values) could be communicated to the trigger system.

Deriving Trigger primitives with the ATLAS FELIX Card

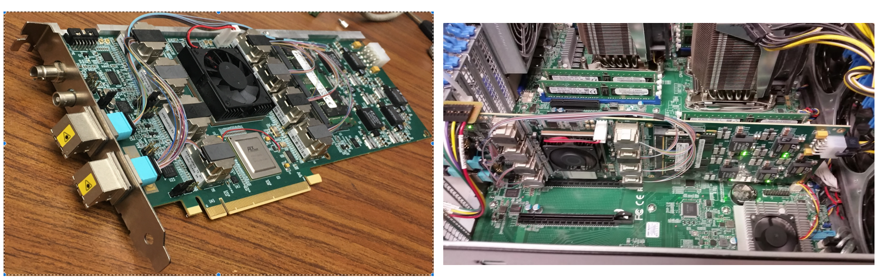

Figure 1: A FELIX card (on the left), mounted in a host PC on the right.

The ATLAS collaboration has designed a general-purpose PCIe card with a fast Xilinx Kintex UltraScale FPGA at its core (Fig. 1). The card has up to 48 high-speed (10GBit/s) bi-directional fiber inputs, and a 16-lane PCIe connection to the host computer. This card is already in use for the sPHENIX TPC readout, so experience with this hardware already exists. This proposal would also draw on already existing and proposed work characterizing various types of calorimeter modules, which could be used with the same workhorse “RCDAQ” data acquisition system [1], minimizing the duplication of development efforts. RCDAQ has already been in routine use for many EIC-related R&D setups, such as the lab setups at BNL and Stony Brook, and the various test beam campaigns at the Fermilab Test Beam Facility [2].

The large number of high-speed inputs of the FELIX card allow to transmit a substantial amount of front-end data to the card for further processing. For example, the full raw data reduced to 8bit resolution of 1000 EmCal channels could be sent to this card in less than 15 μs for processing.

We are proposing

- to select an existing system to digitize the signals from an EmCal subsystem with Silicon Photomultipliers (SiPMs) with optical readout to connect to the FELIX card. A viable system would be the sPHENIX calorimeter digitizer card with 64 channels. Other commercial systems are readily available in the form of evaluation boards.
- to re-use an existing and now-unused EmCal prototype to digitize and process actual data. This could be data from cosmics, or simulated data with certain properties that could be made to look like they are coming from the detector.
- demonstrate the feasibility of implementing the code to derive trigger primitives in the FELIX card.
- evaluate and if possible demonstrate the ability of this system to run in trigger-less, or streaming, mode.

Schedules, Milestones, Deliverables, and Funding Requests

We will first procure a FELIX card and a host PC, and will obtain or borrow a card suitable to transmit data to the FELIX card at 10GBit/s speeds. It might be possible to use the FPGA on the card itself to generate the fake data. We will likely be able to initially use the existing sPHENIX cards for short periods of time before we have our own card.

We will implement the readout of the FELIX card in our standard data acquisition system "RCDAQ" in order to be able to analyze and work with the data easily.

We will select and, if necessary, procure a number of digitizer cards.

The work breakdown by quarter:

Activity	Q1	Q2	Q3	Q4
Procure a FELIX card and host system	x			
Implement the FELIX readout in RCDAQ	x	x		
Select and procure a digitizer front-end card	x	x		
Develop the FPGA and CPU code		x	x	x
Test the system and characterize the performance		x	x	x
Final report				x

The list of deliverables

Deliverables	Q1	Q2	Q3	Q4
Demonstrate a commissioned development system			x	
Report obtained performance parameters				x
Final report				x

Breakdown of the funding request:

Funding Request	Amount
FELIX Card and host system	$22,000
2 Digitizer cards	$5000
FPGA Software and licenses	$12,000
Programming course	$3000
1/2 post-doc for 1 year	$35,000
Travel funds	$12,000
Total	**$66,000**

Summary

Drawing on existing expertise, hardware, and already planned work, we are proposing an additional low-cost effort to study the performance of an EmCal trigger system by generating trigger primitives in the front-end electronics. We will also be able to test the feasibility of running the EmCal readout in a trigger-less streaming mode.

References

[1] Martin L. Purschke. RCDAQ, a lightweight yet powerful data acquisition system. http://www.phenix.bnl.gov/ purschke/rcdaq_doc.pdf, 2012.

[2] B. Azmoun, B. DiRuzza, A. Franz, A. Kiselev, R. Pak, M. Phipps, M. L. Purschke, and C. Woody. A study of a mini-drift GEM tracking detector. *IEEE Transactions on Nuclear Science*, 63(3):1768–1776, June 2016.